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College of Agriculture
College of Engineering

Water Resources in Indiana: Past, Present and Future

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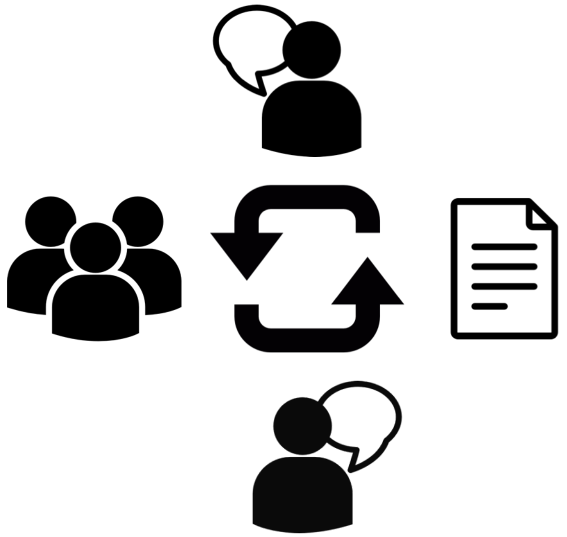
Purdue Climate Change Research Center

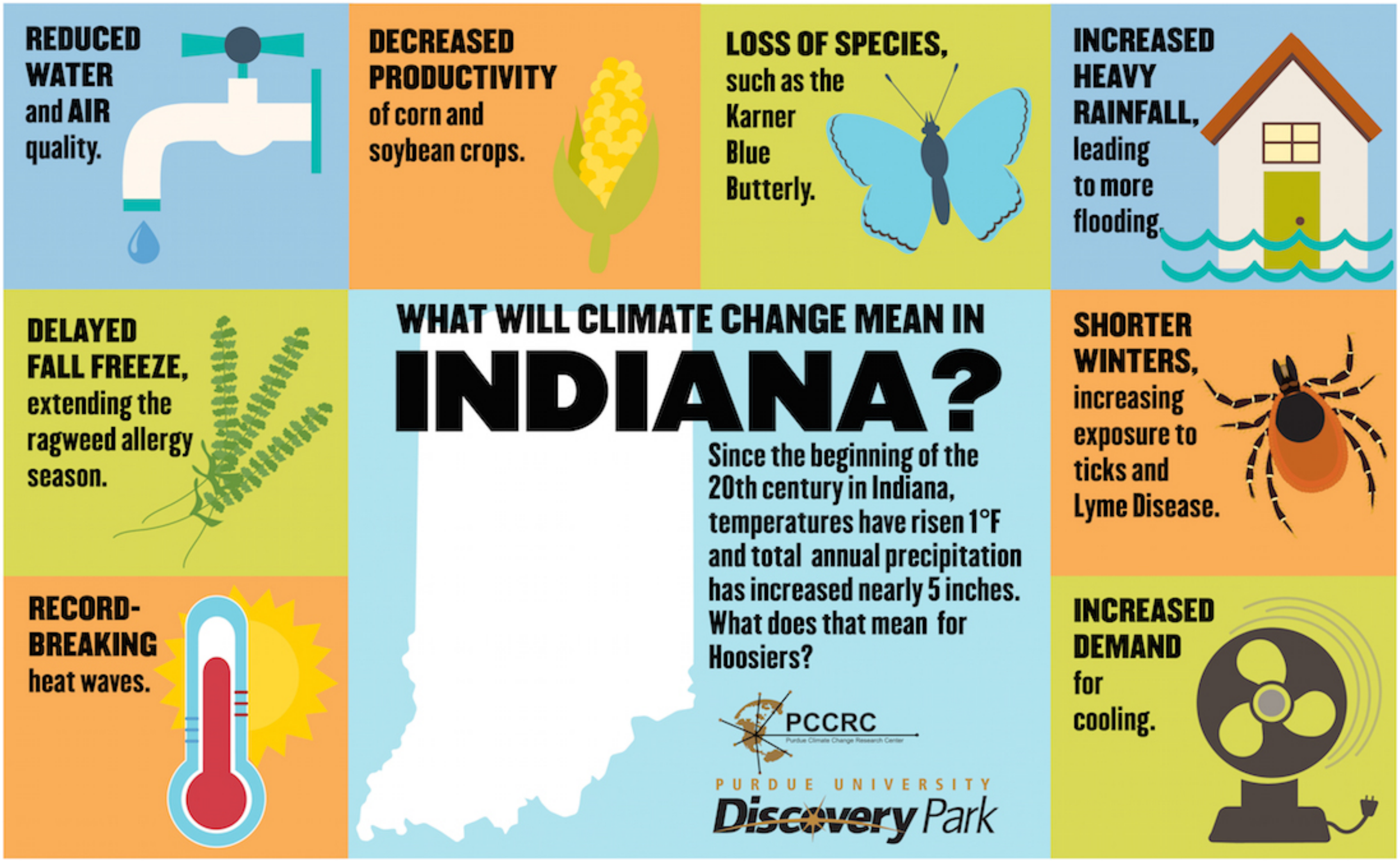
LTAP Stormwater Drainage Conference, February 6, 2019

IN CCIA
Indiana Climate Change Impacts Assessment

OBJECTIVE:
The **IN CCIA** will bring together the best available climate change research into a series of reports that will help Hoosiers better understand climate change-related risks so they can **prepare for challenges** and **capitalize on opportunities**.

- Led by the Purdue Climate Change Research Center (PCCRC)
- Contributions from nearly 100 experts across the state
- Actively engage stakeholders throughout this process
- Reports started rolling out in 2018
- The Water Resources Report will come out in April 2019




REDUCED WATER and AIR quality.
DECREASED PRODUCTIVITY of corn and soybean crops.
LOSS OF SPECIES, such as the Karner Blue Butterly.
INCREASED HEAVY RAINFALL, leading to more flooding.
DELAYED FALL FREEZE, extending the ragweed allergy season.
WHAT WILL CLIMATE CHANGE MEAN IN
INDIANA?
Since the beginning of the 20th century in Indiana, temperatures have risen 1°F and total annual precipitation has increased nearly 5 inches. What does that mean for Hoosiers?
PCCRC
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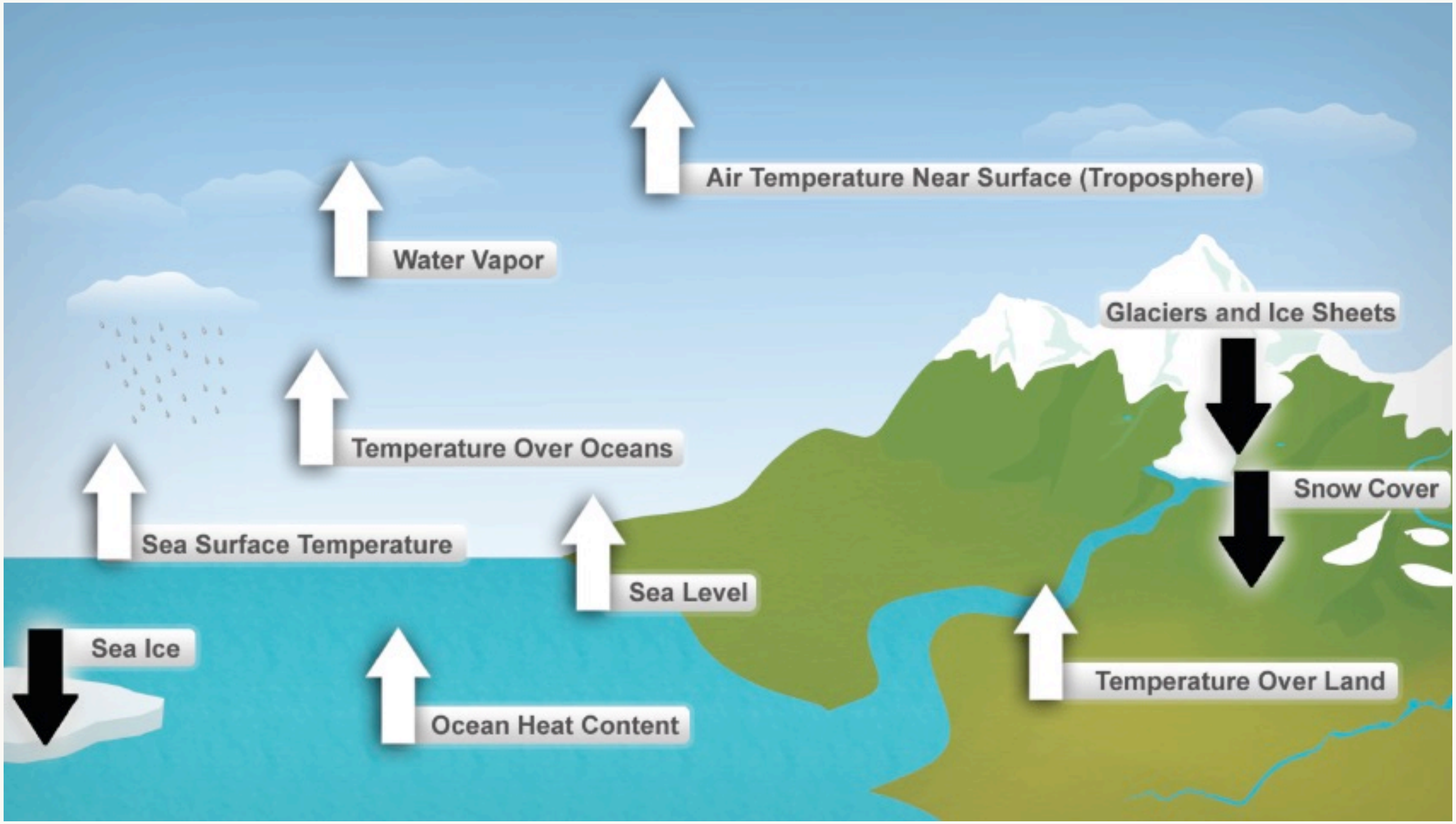
Discovery Park
SHORTER WINTERS, increasing exposure to ticks and Lyme Disease.
RECORD-BREAKING heat waves.
INCREASED DEMAND for cooling.


Agriculture
Climate
Ecosystems
Energy
Health
Infrastructure
Tourism & Recreation
Water Resources

Historical Changes to Indiana Water Resources

Long-Term Indicators of Change



Source: National Climate Assessment, http://nca2014.globalchange.gov/

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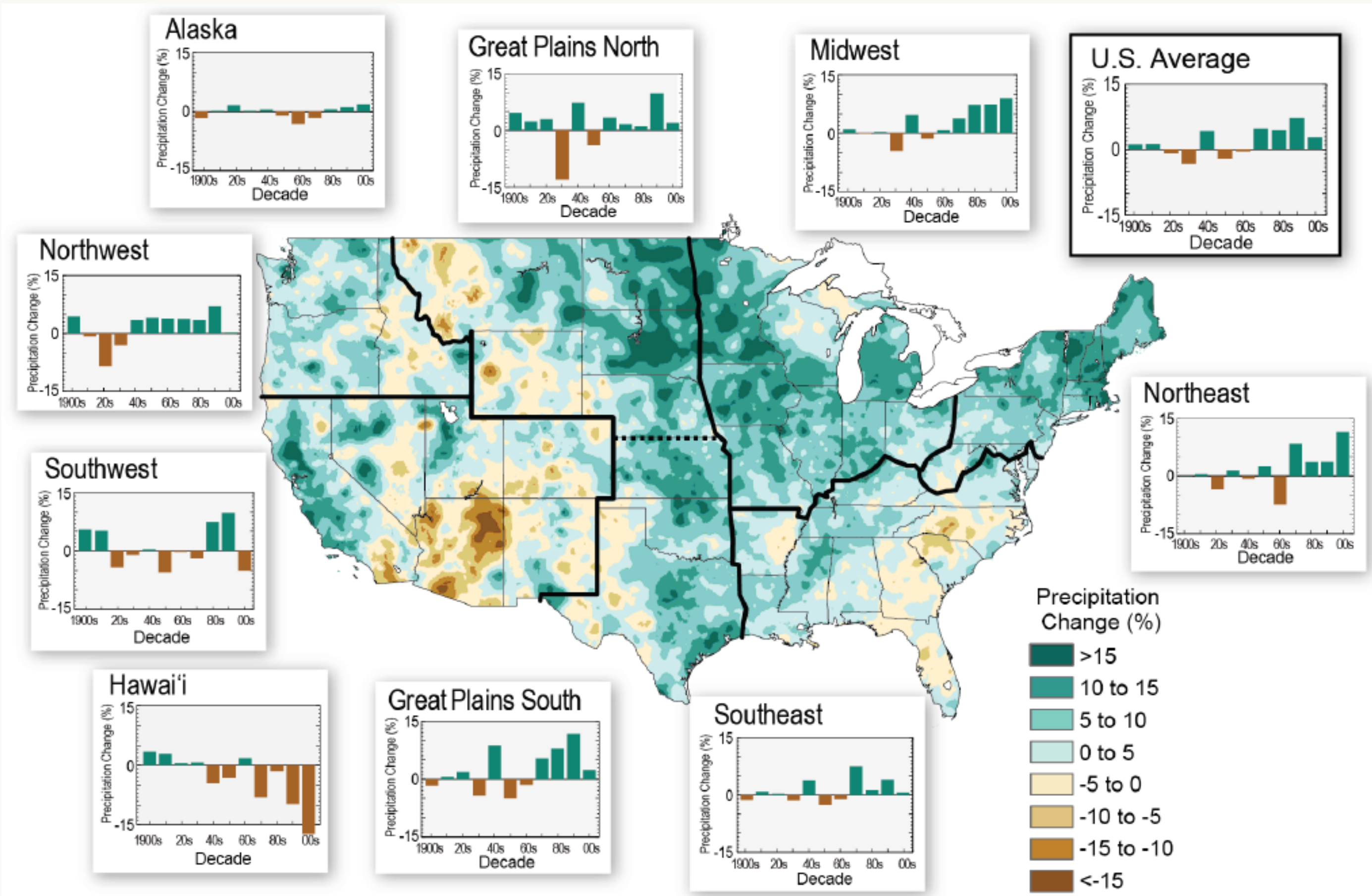
Observed U.S. Precipitation Change



Source: National Climate Assessment, http://nca2014.globalchange.gov/

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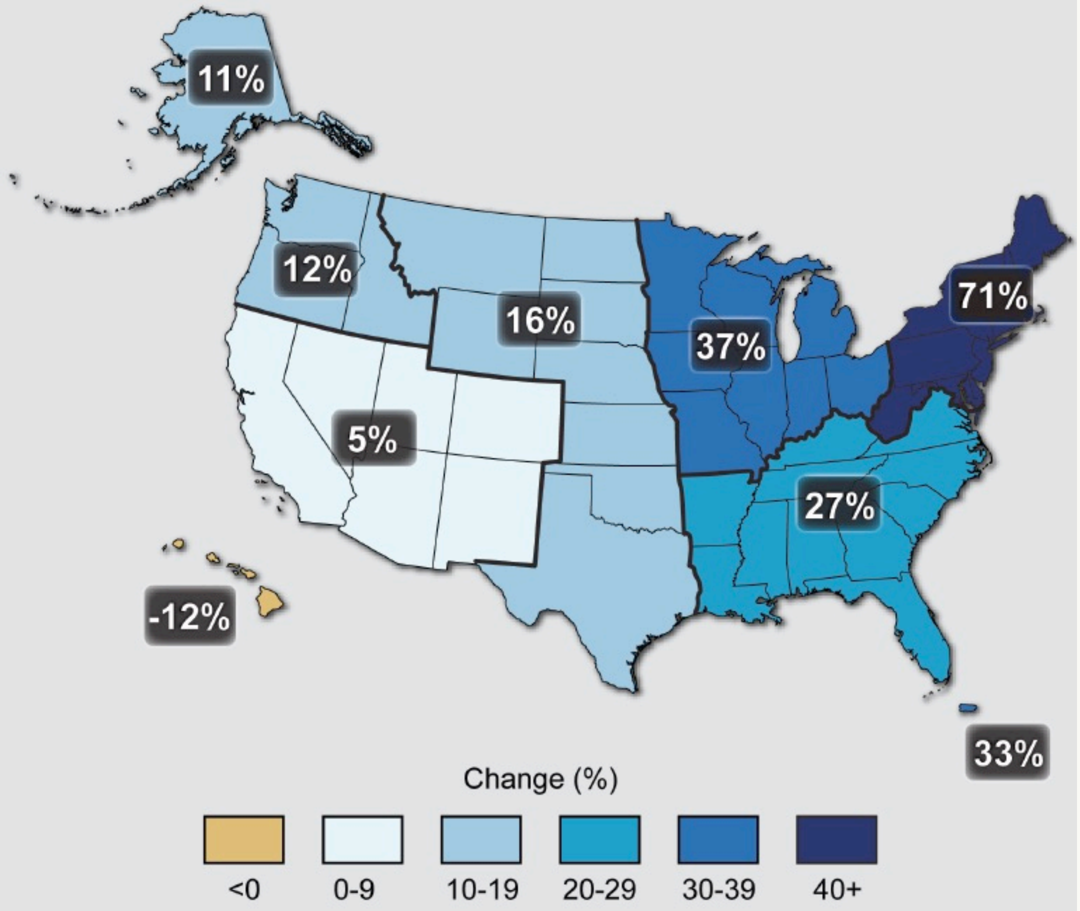
Change to Extreme Precipitation



- Based on observations from 1950 to 2012
- Change in the **heaviest 1%** of precipitation storm events

Source: National Climate Assessment, http://nca2014.globalchange.gov/

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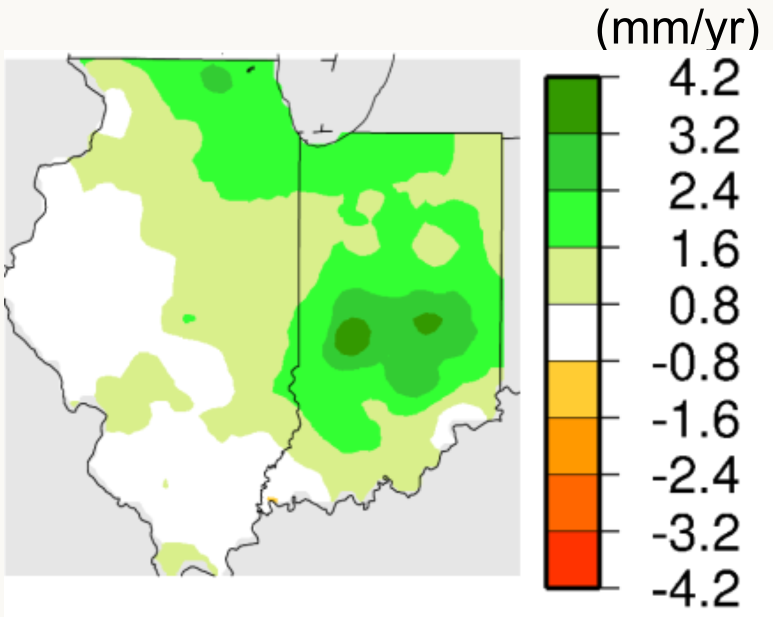
Water Resource Trends (1916-2007)

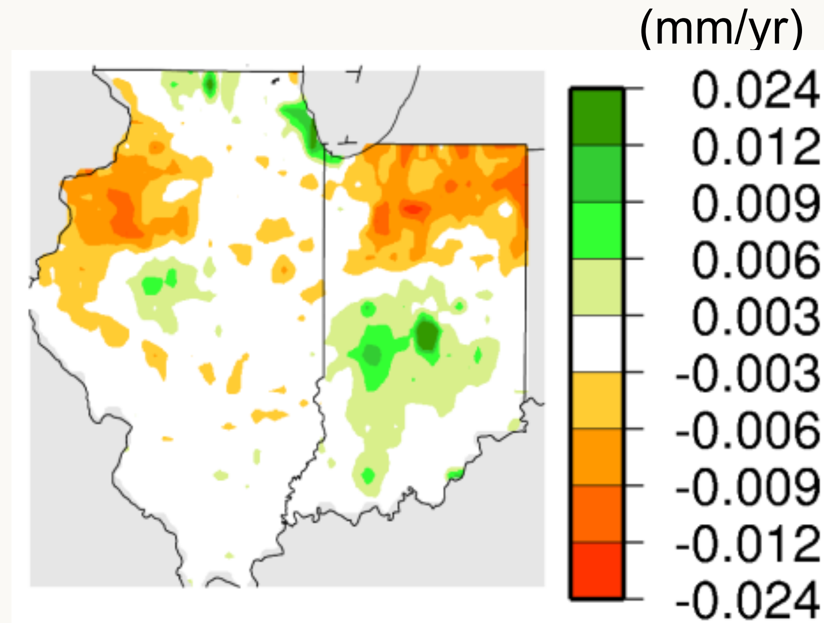
Precipitation

Observed



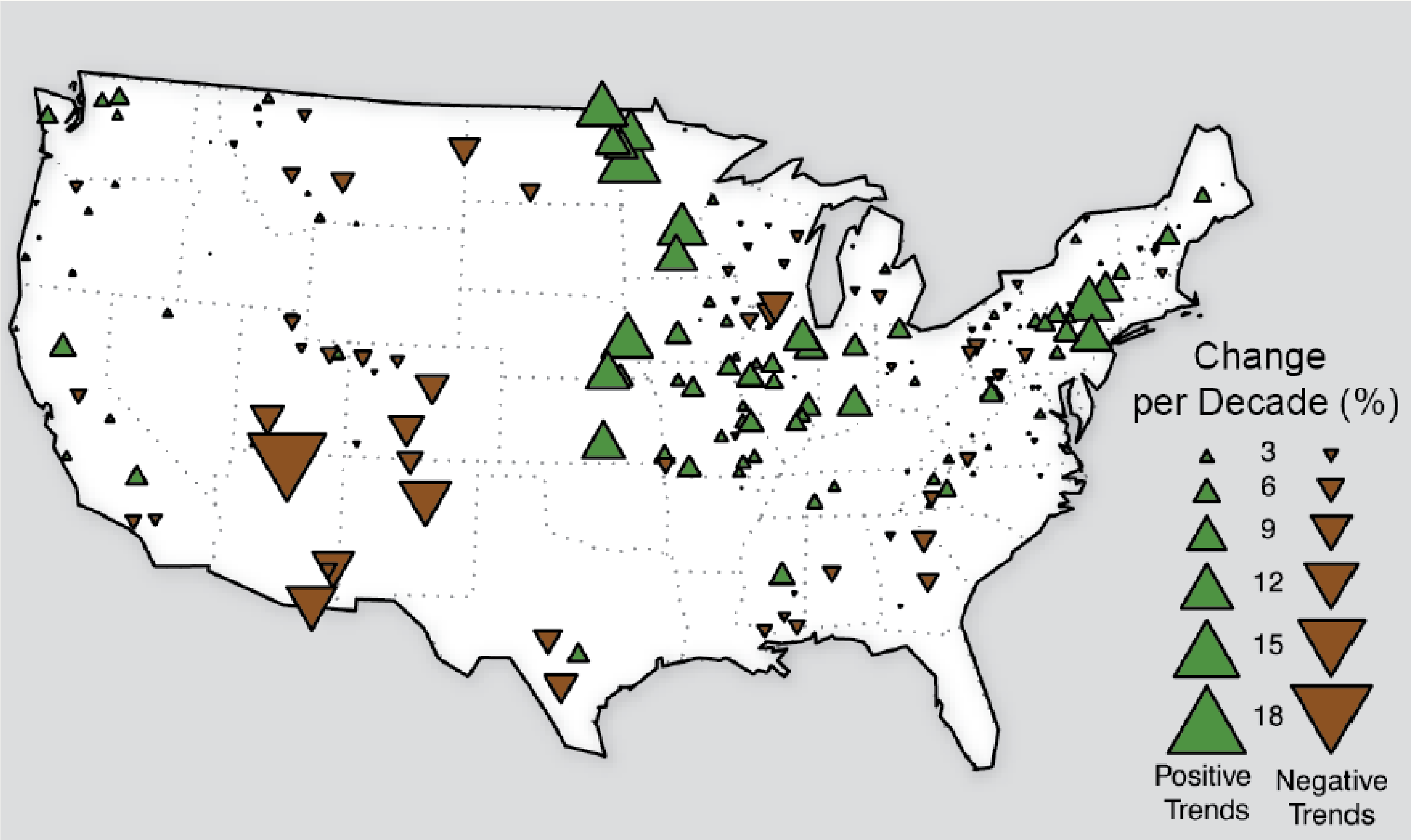
Soil Moisture

Simulated



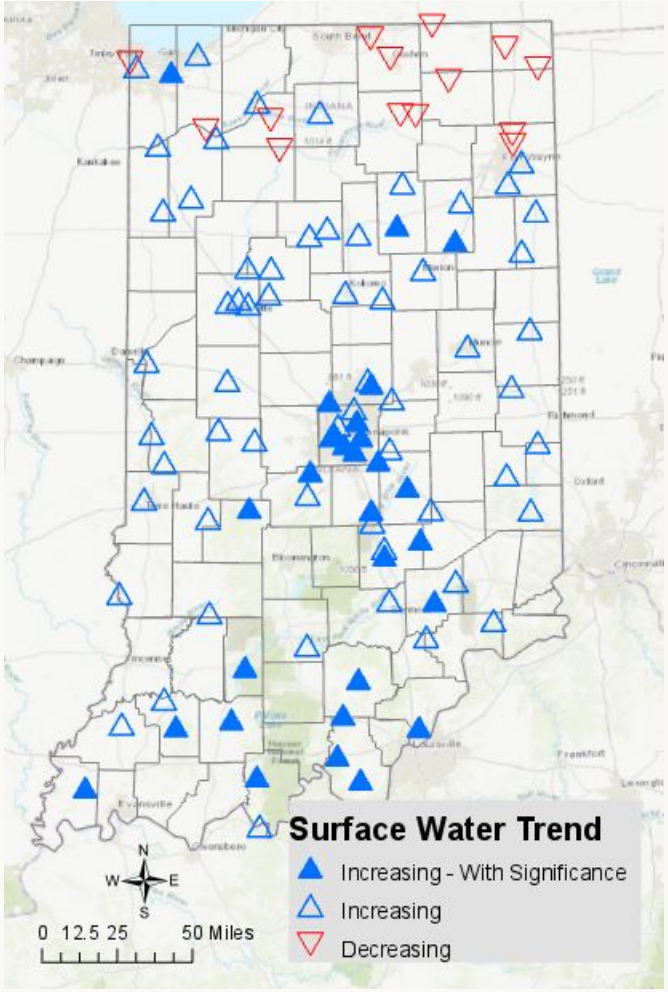
Mishra and Cherkauer, 2010

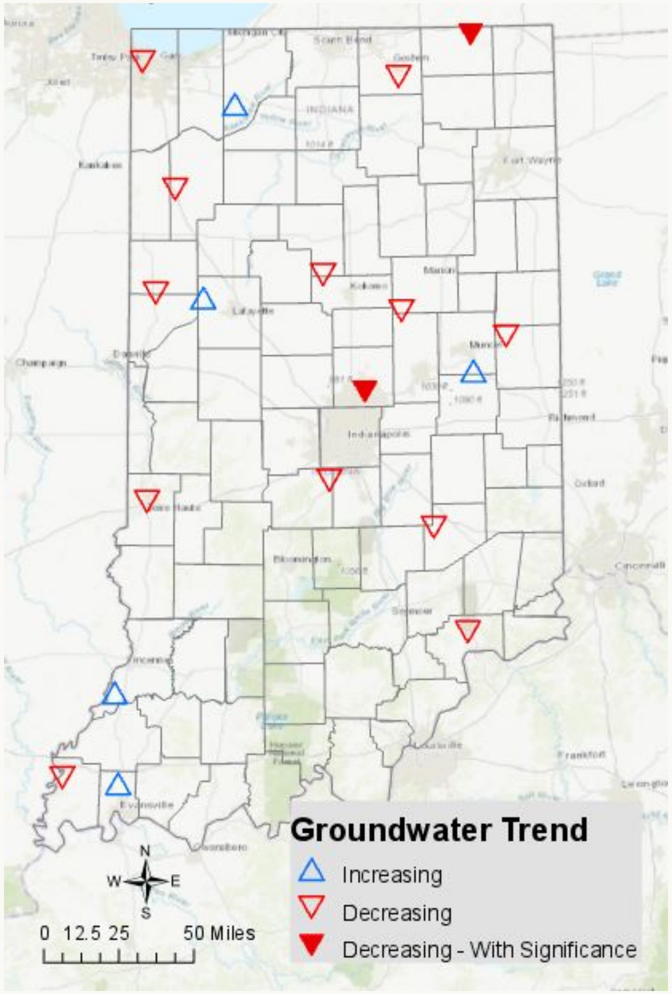
Observed Trends in Flood Magnitude



Source: National Climate Assessment, http://nca2014.globalchange.gov/

Water Resource Trends (1988-2017)





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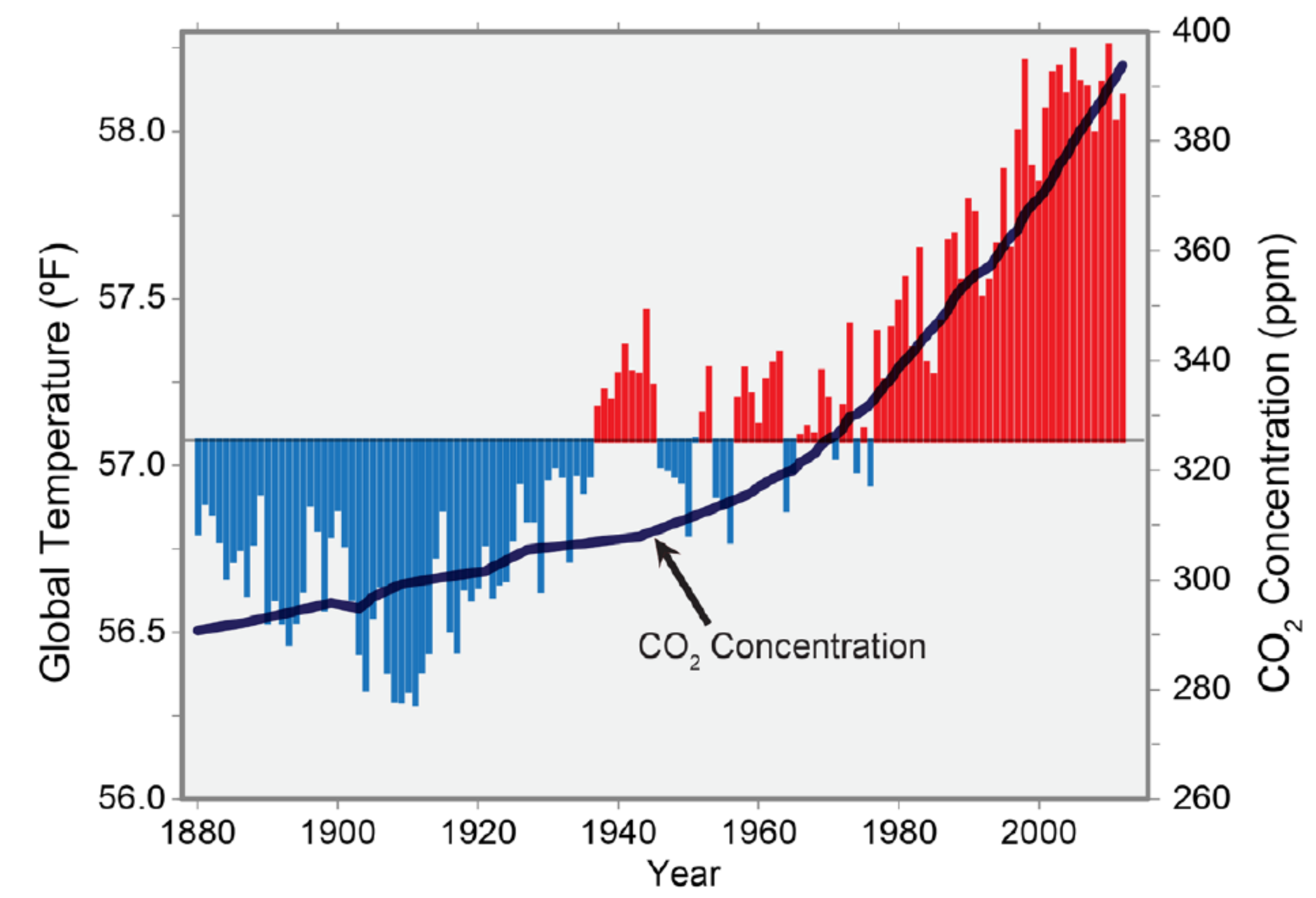
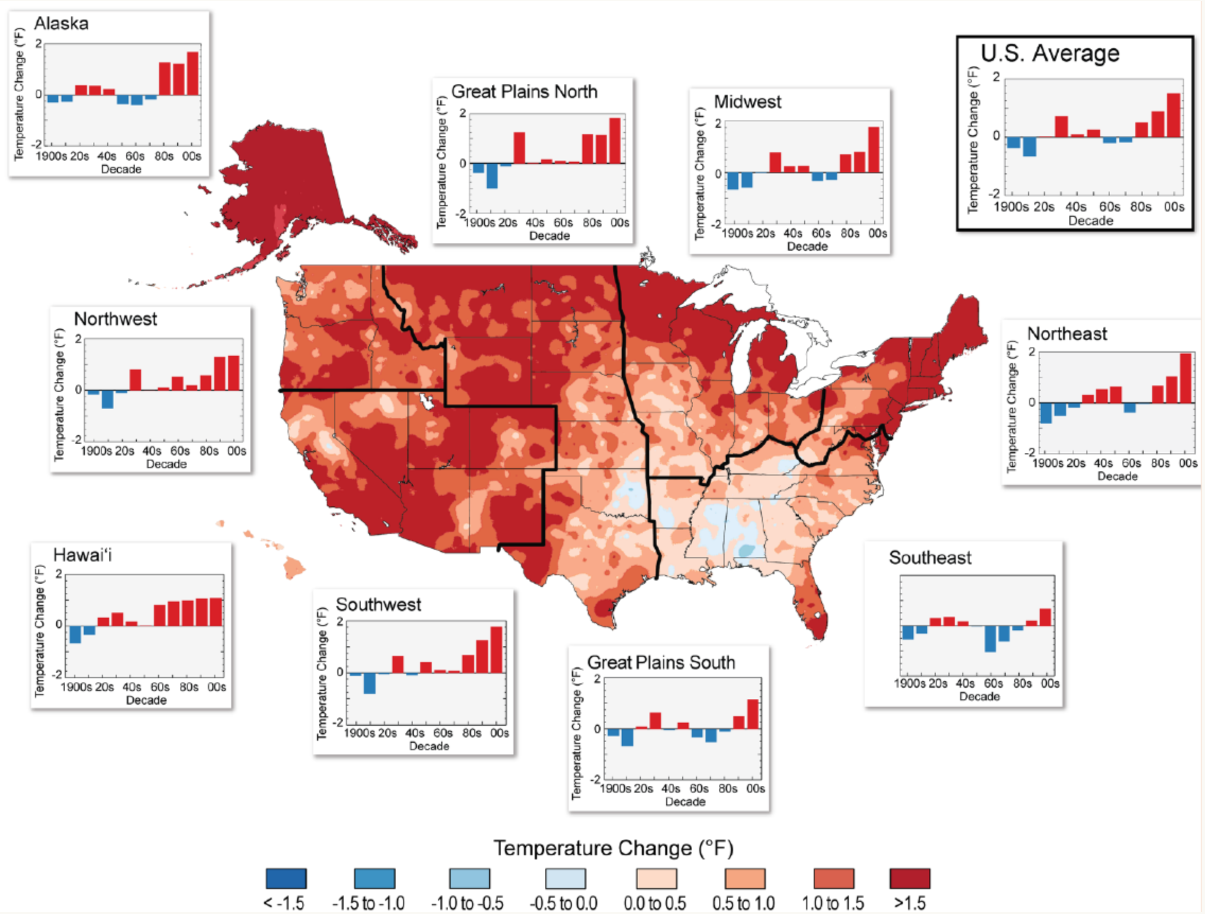
Kines and Cherkauer, in review
www.agry.purdue.edu/indiana-waters

Global Temperature and CO2



Source: National Climate Assessment, http://nca2014.globalchange.gov/

Observed U.S. Temperature Changes



Source: National Climate Assessment, http://nca2014.globalchange.gov/

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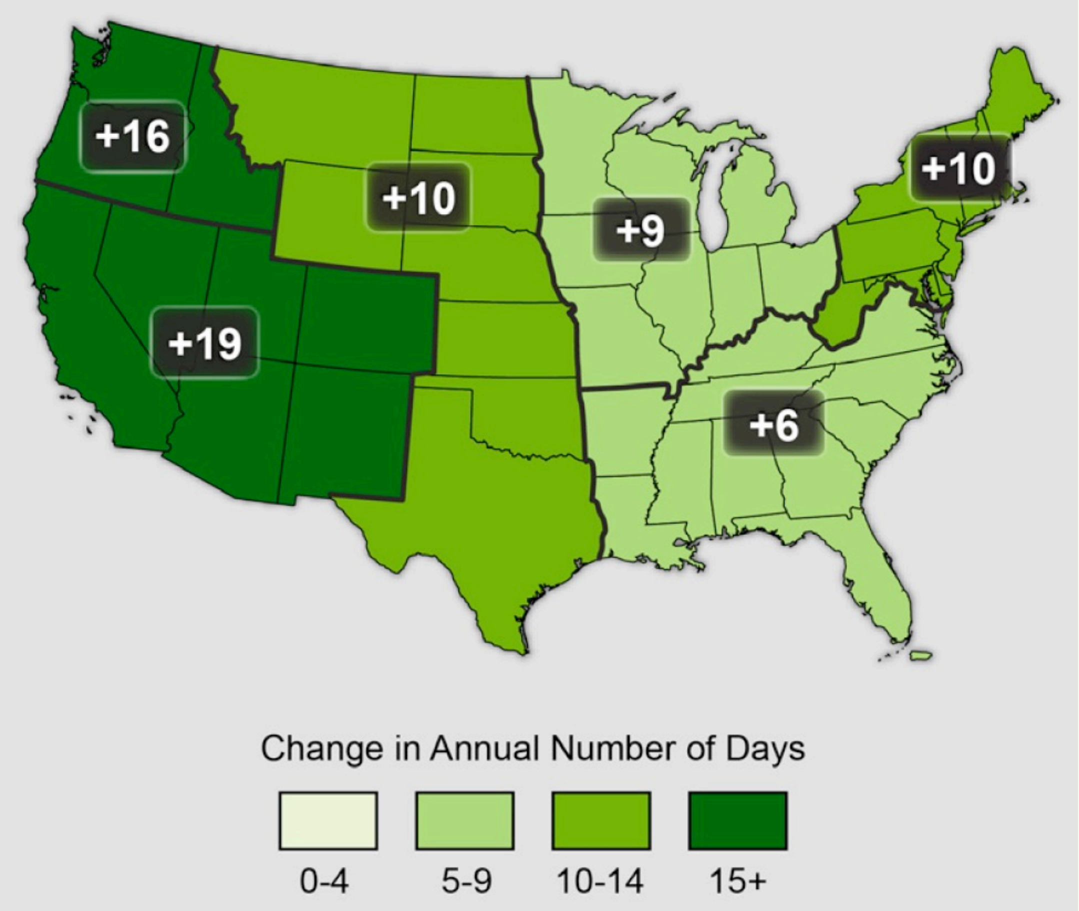
Observed Increase in Frost-Free Season Length



Source: National Climate Assessment, http://nca2014.globalchange.gov/

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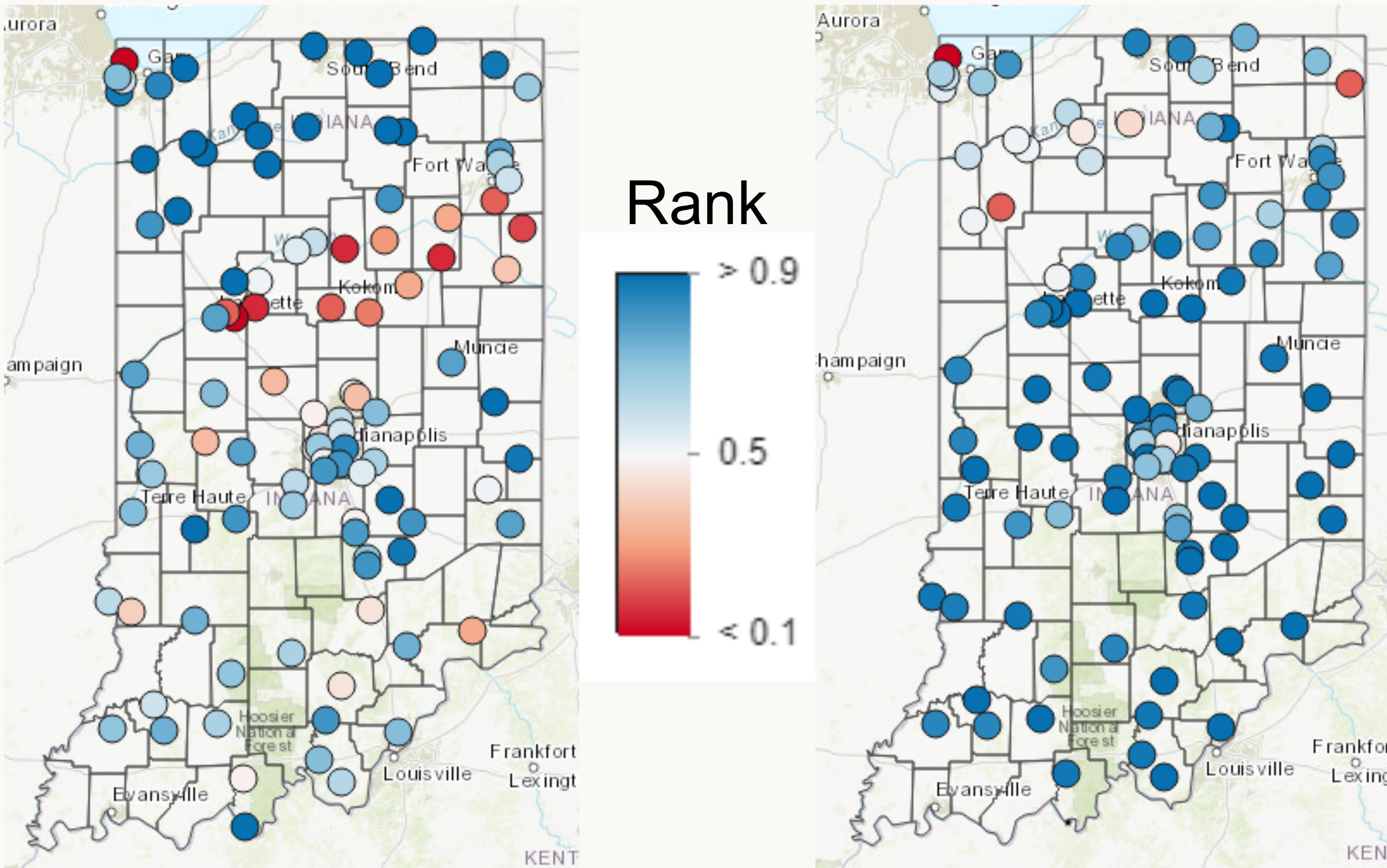
Current State of Indiana Water Resources

Analysis for the current water year can be found at:

https://www.agry.purdue.edu/indiana-water

Surface Water (Streamflow) Rank

Maximum Flow Rank   End of Year Rank



WY 2017 ranked versus previous 28 years

Source: https://www.agry.purdue.edu/indiana-water

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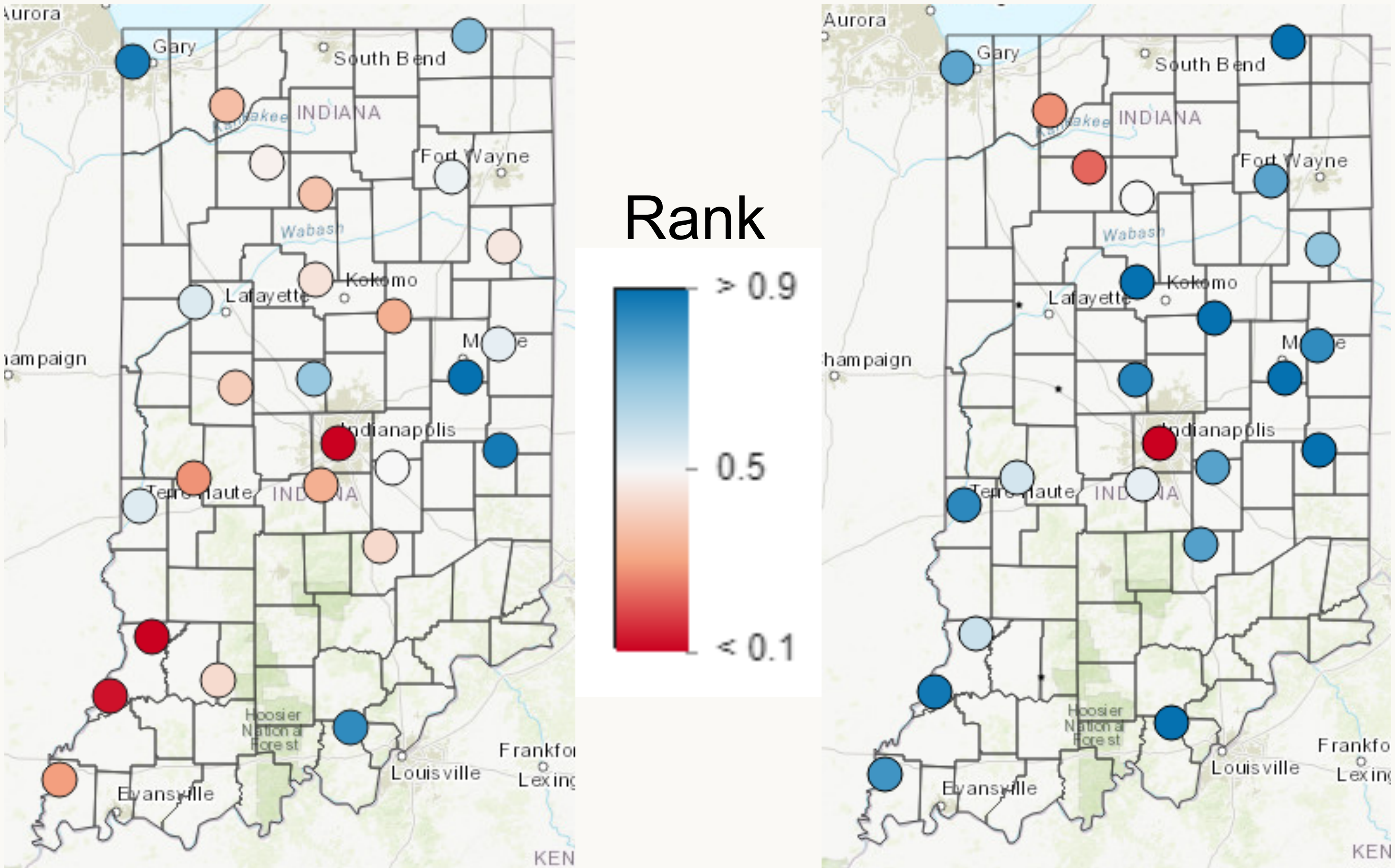
Groundwater (Water Table) Rank

Mean Flow Rank

End of Year Rank



WY 2017 ranked versus previous 28 years

Source: https://www.agry.purdue.edu/indiana-water

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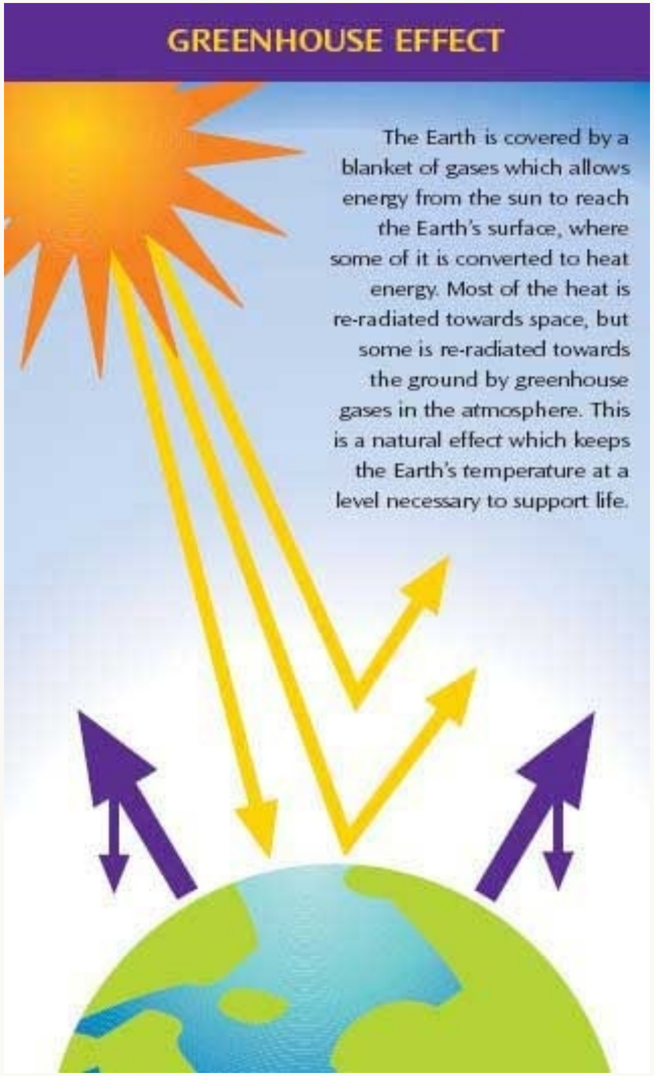
What might the future look like?

The Greenhouse Effect

- It is a naturally-occurring phenomena
  - water vapor, carbon dioxide, methane, and other naturally-occurring gases trap heat in the atmosphere
- Sustains life here on Earth
  - Without it, average temperature would be about –20°F instead of 55°F



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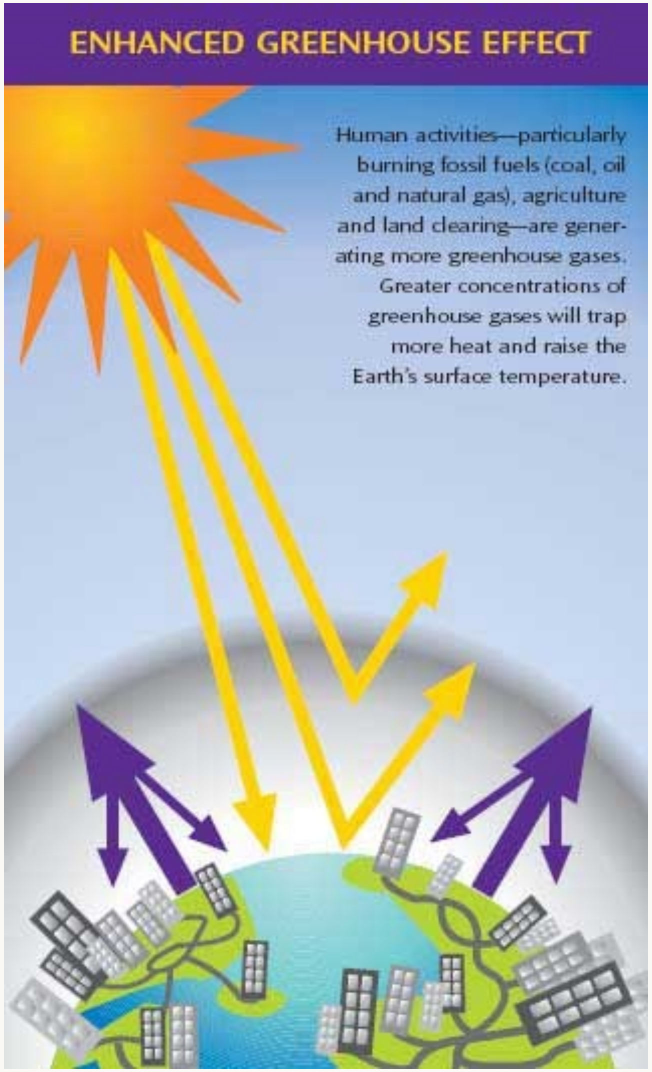
So What is Global Warming?

- The problem is that we are <u>increasing</u> the concentration of heat-trapping gases

- This is like wrapping an extra blanket around the Earth

- This blanket is the “enhanced greenhouse effect”, or *global warming*



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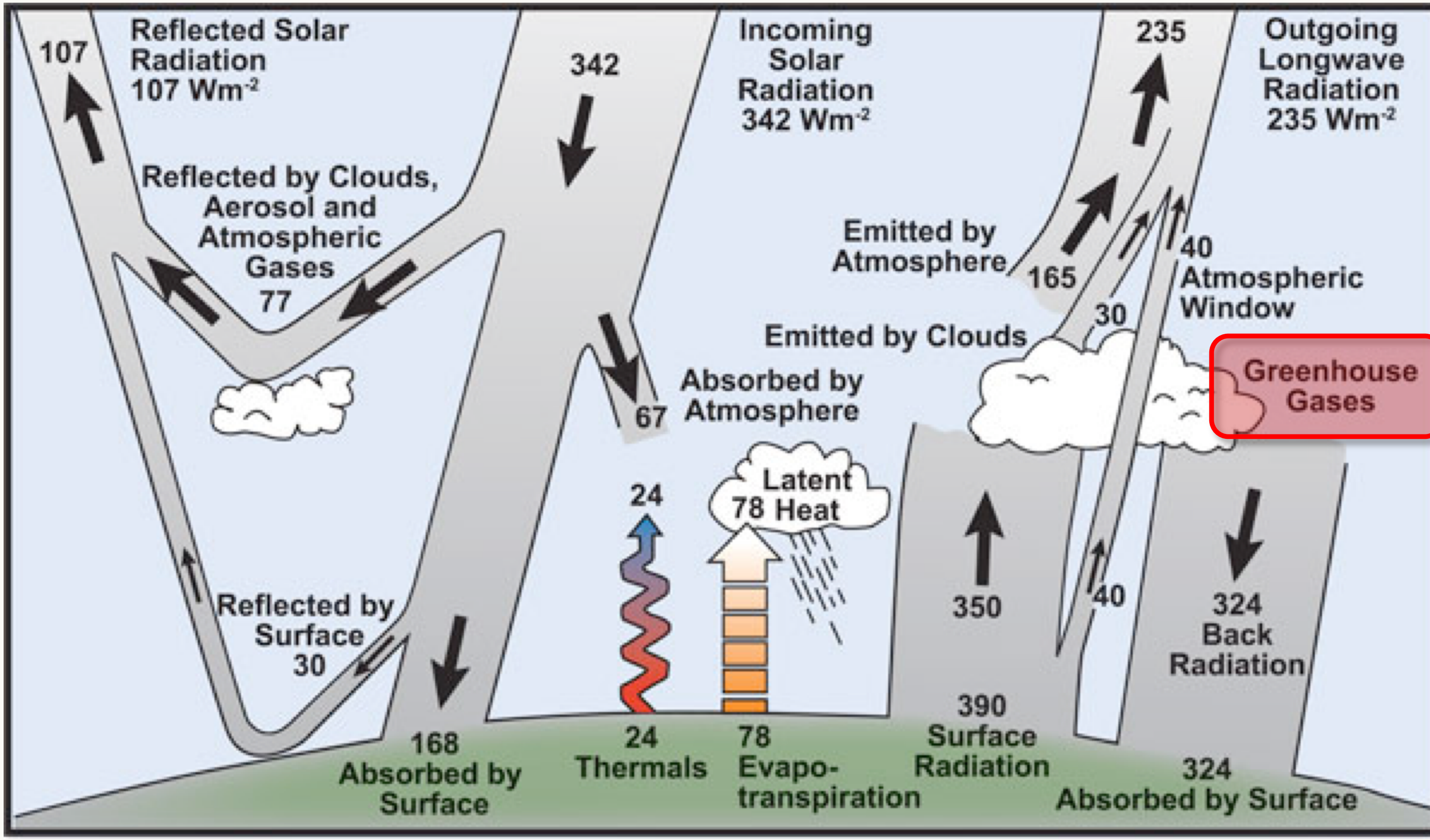
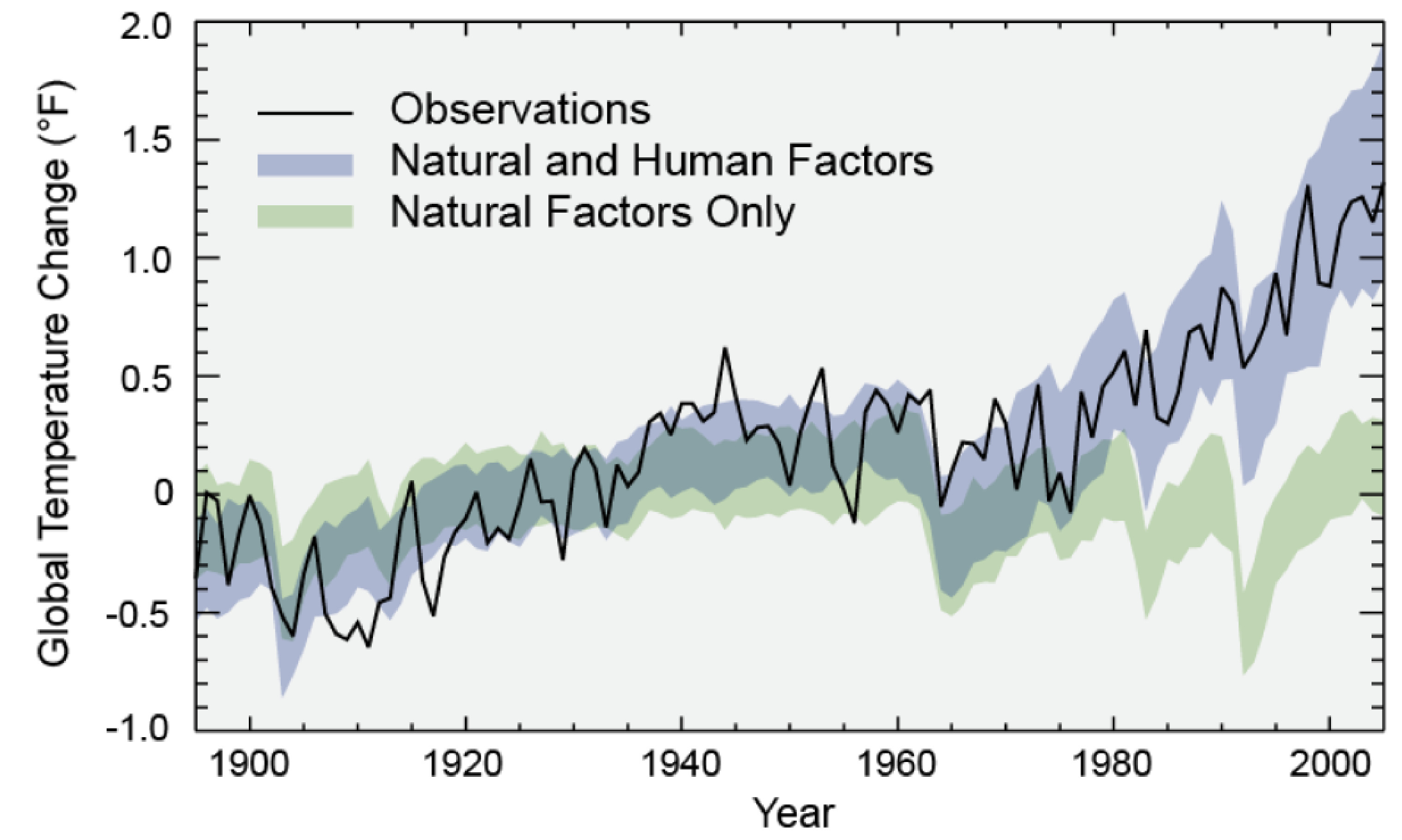
Global Energy Balance



Heat flux from Earth's core ≈ 1/10,000 of solar radiati

From: southwestclimatechange.org

Separating Human from Natural Influences on Climate



Source: National Climate Assessment, http://nca2014.globalchange.gov/

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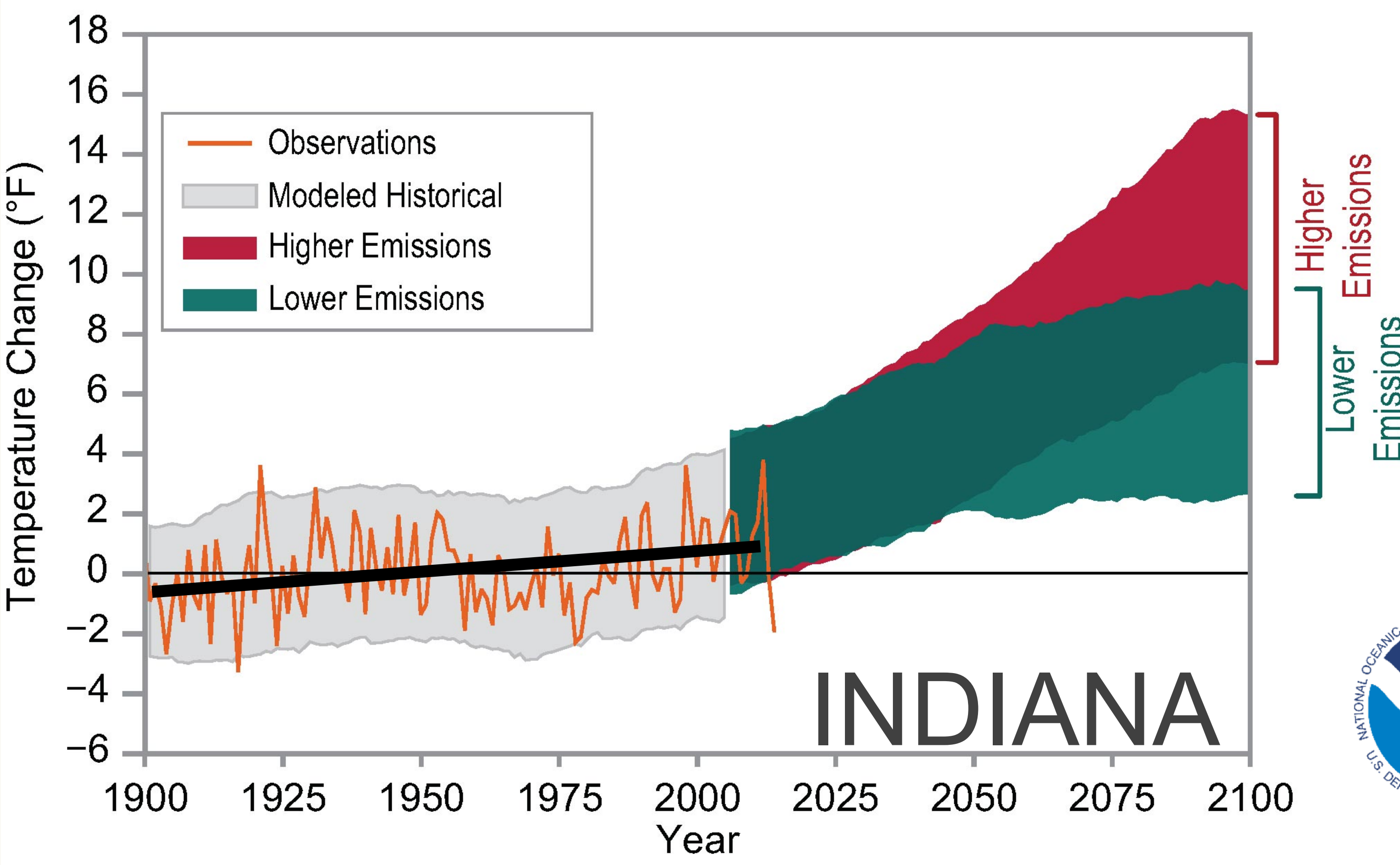
Annual Statewide Average Temperature



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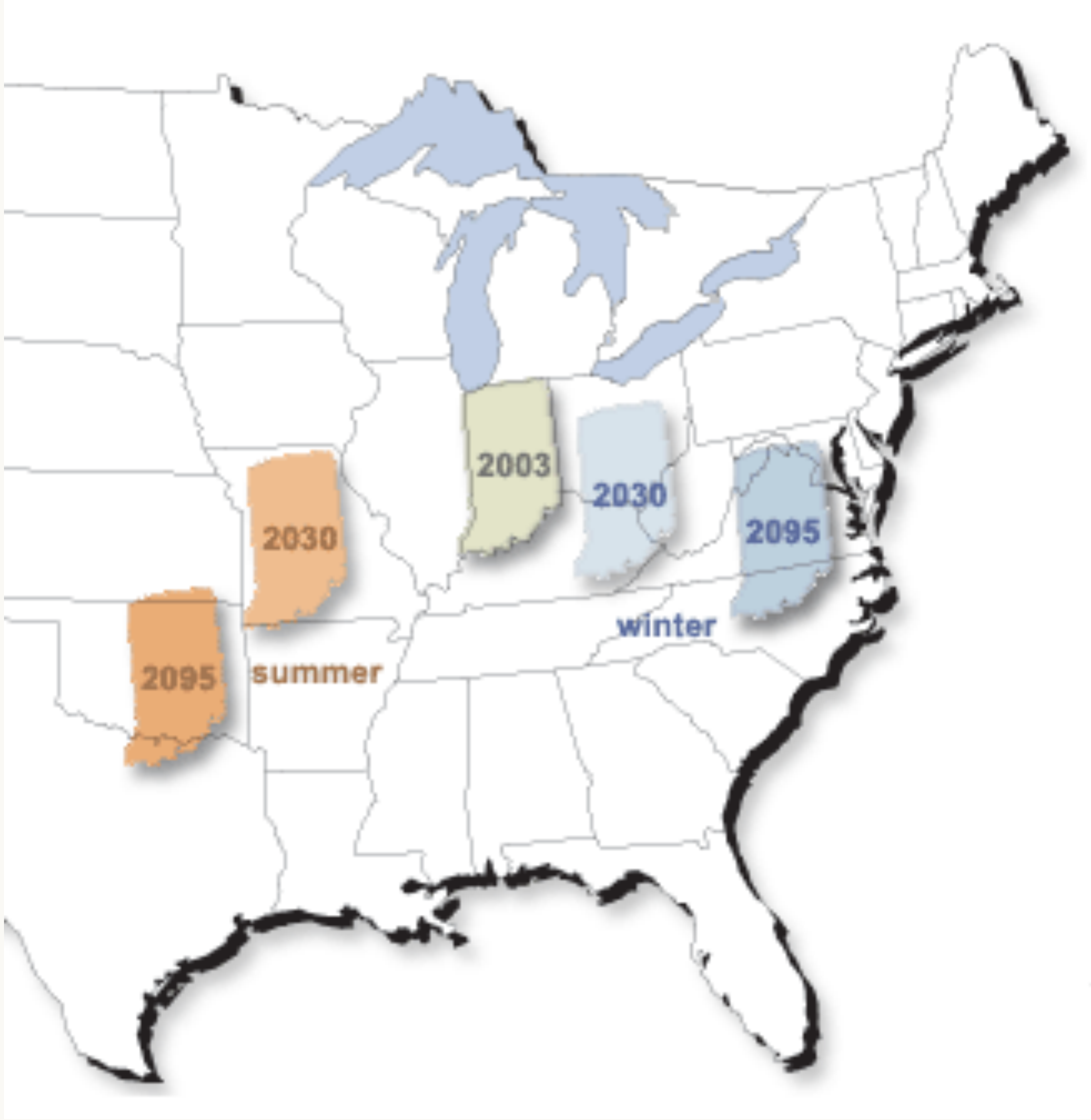
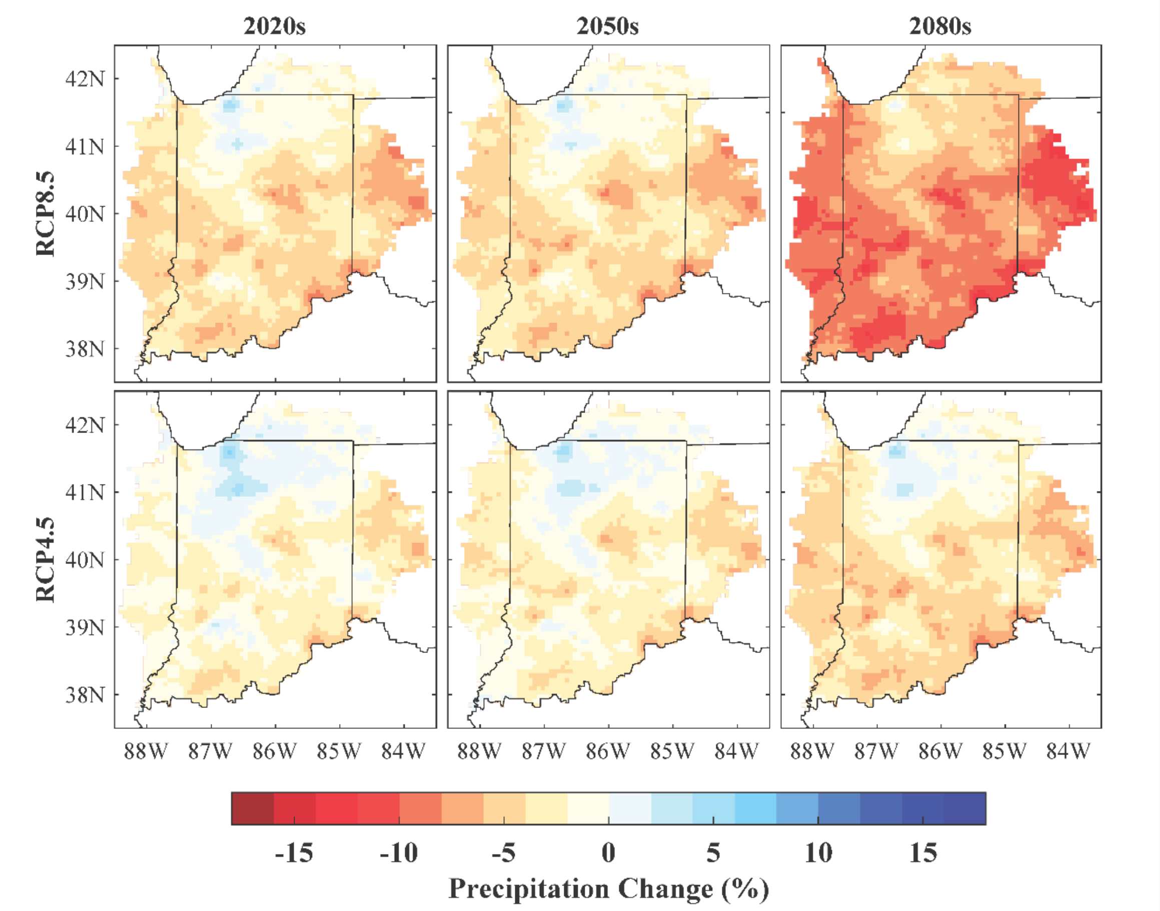
What Might Indiana Be Like?



Change in Summer Precipitation



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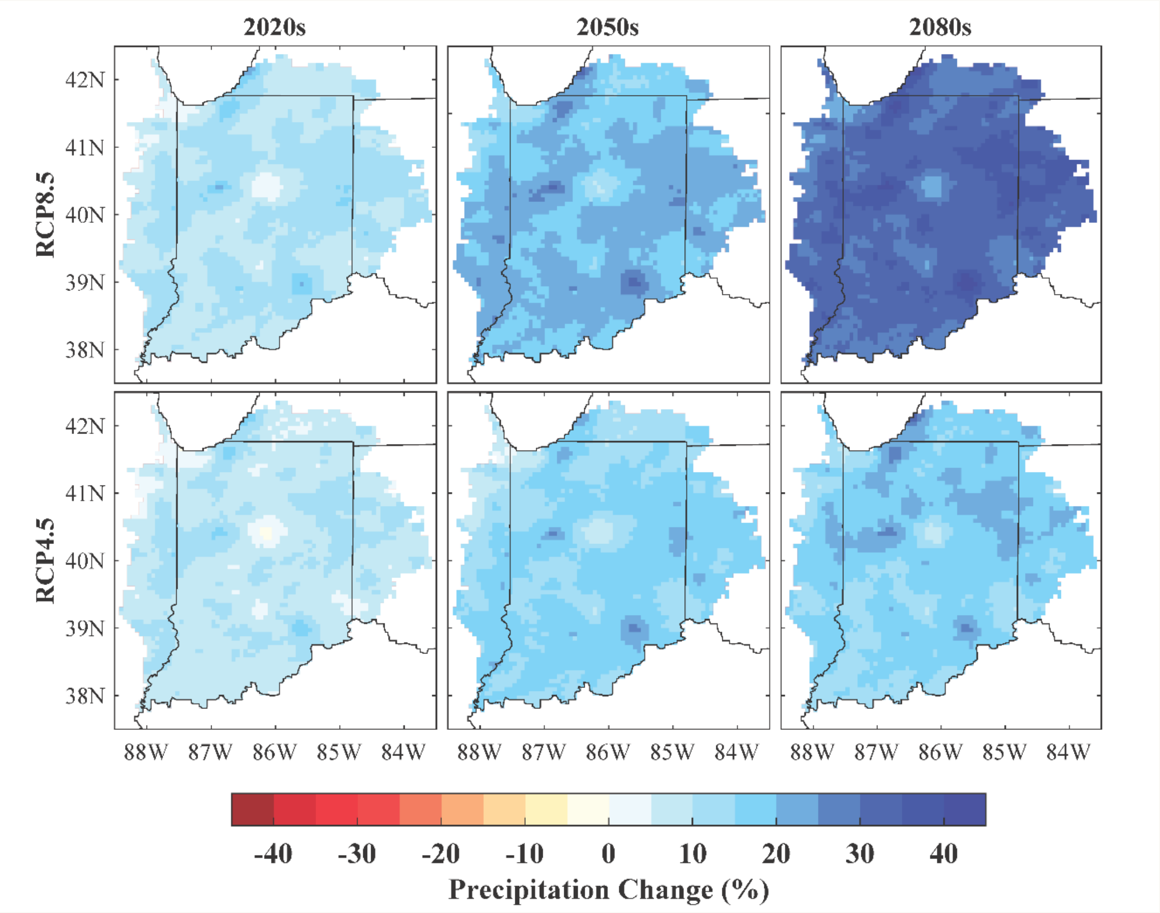
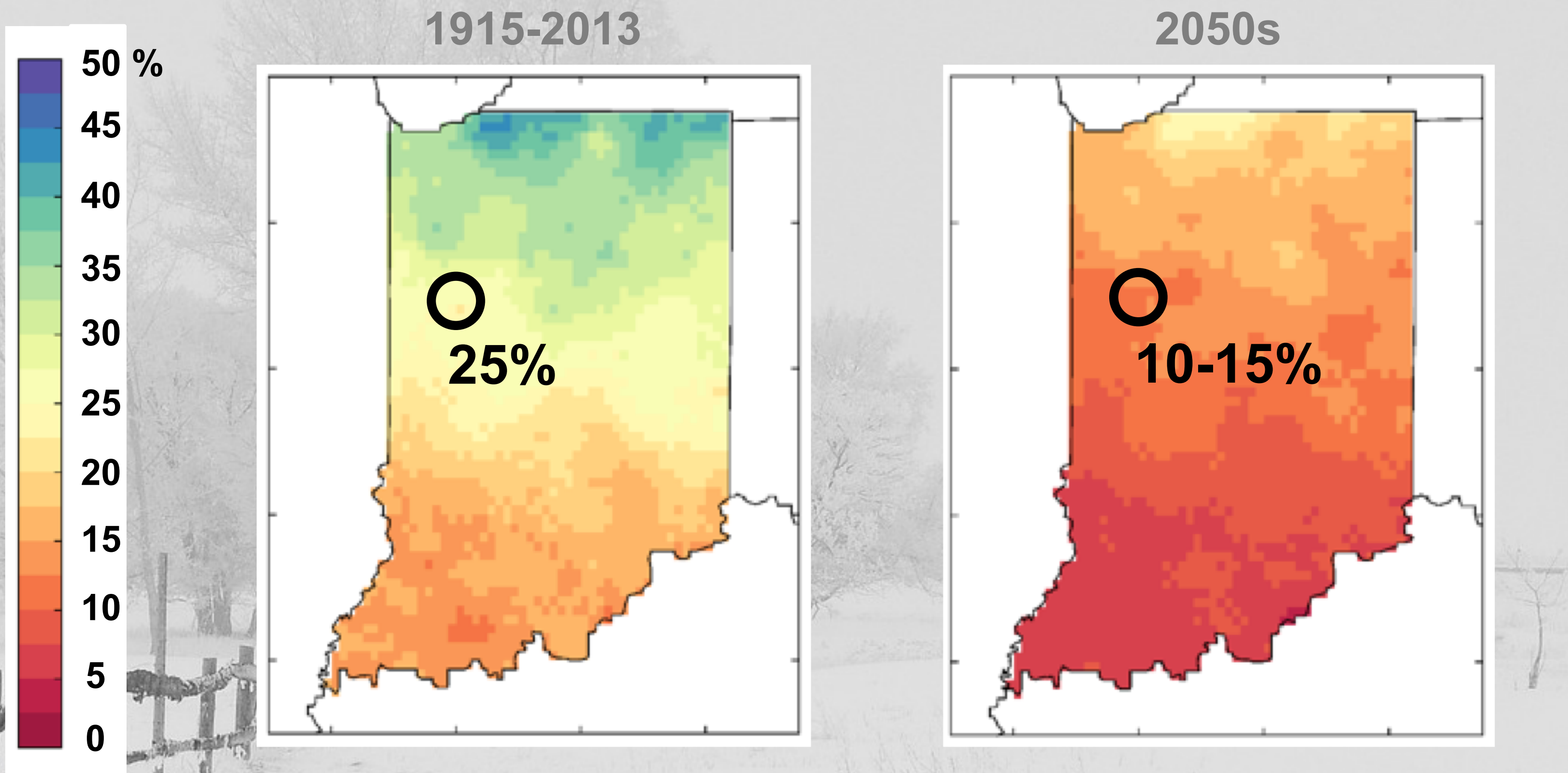
Change in Winter Precipitation



Rain or Snow?

Fraction of Nov-Mar precipitation falling as snow

IN CCIA

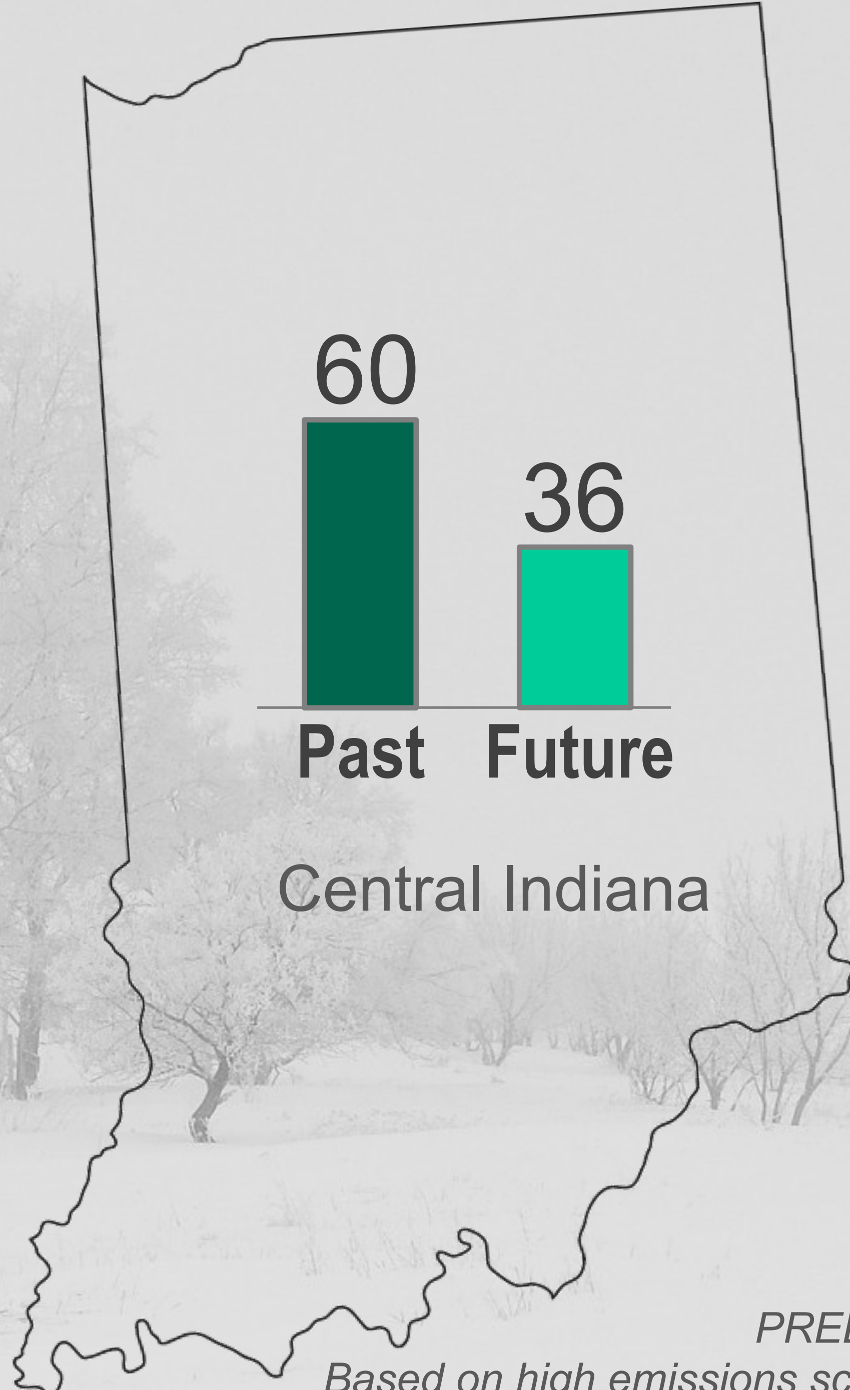


PRELIMINARY DATA

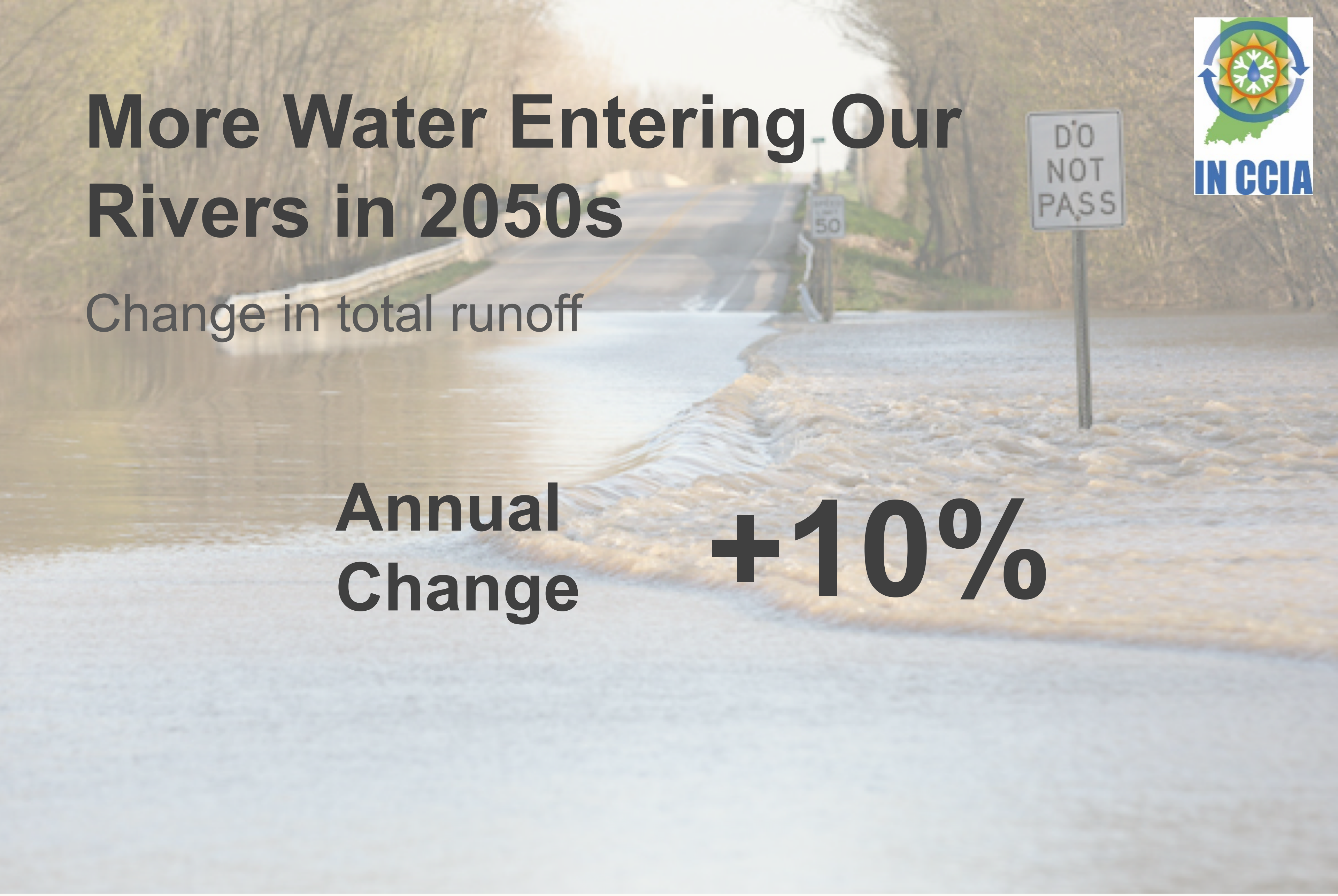
Based on high emissions scenario for 2050s

Days With Snow On The Ground

Annual count



PRELIMINARY DATA
Based on high emissions scenario for 2050s



More Water Entering Our Rivers in 2050s

Change in total runoff

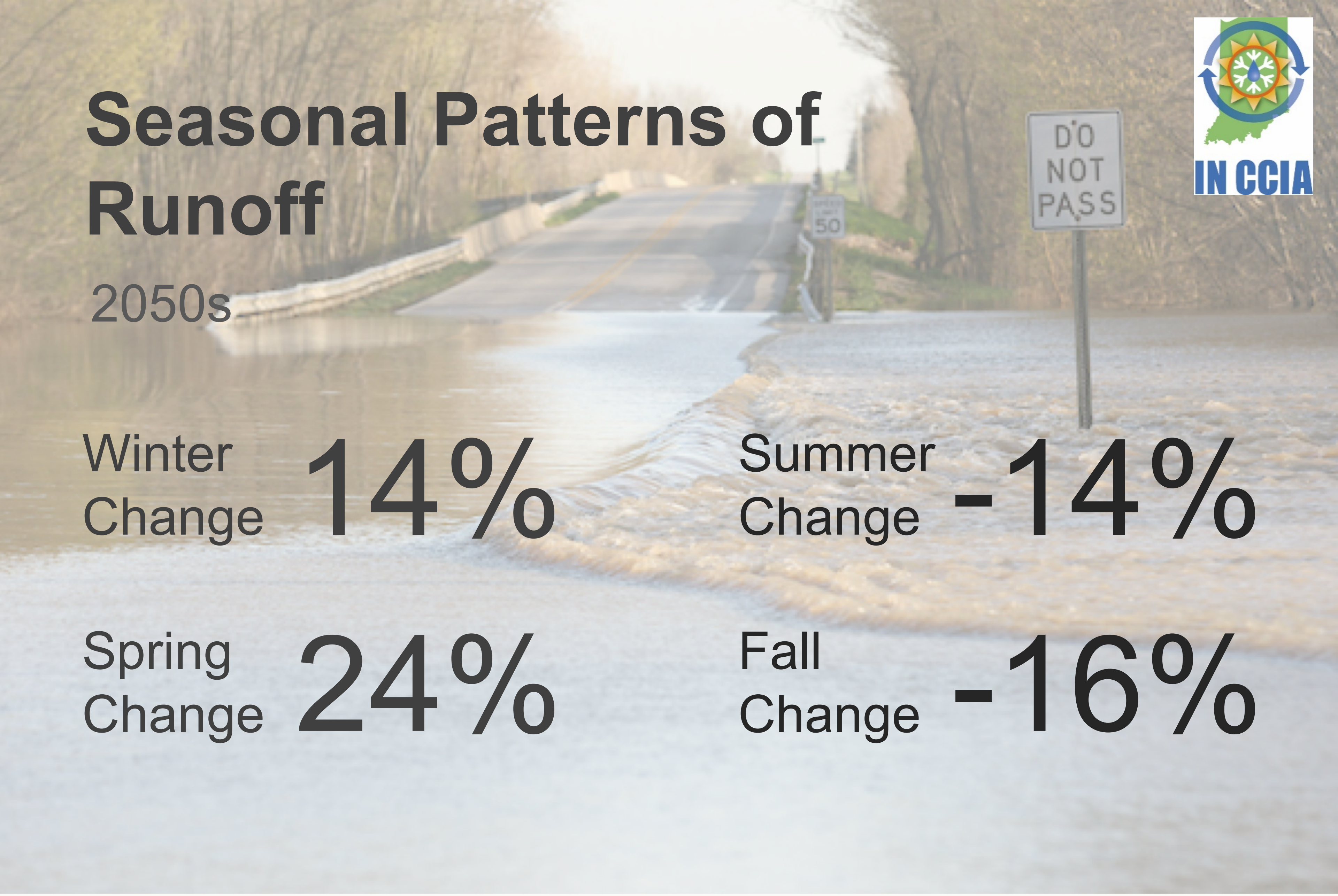
Annual Change **+10%**

Future data based on high emissions scenario;
Percent change is relative to 1984-2013 average
PRELIMINARY DATA

Central Indiana Average

Seasonal Patterns of Runoff

2050s



Winter Change **14%**

Summer Change **-14%**

Spring Change **24%**

Fall Change **-16%**

Future data based on high emissions scenario;
Percent change is relative to 1984-2013 average
PRELIMINARY DATA

Central Indiana Average

Seasonal Patterns of Runoff

2080s

Winter Change **35%**

Summer Change **-24%**

Spring Change **23%**

Fall Change **-23%**

Future data based on high emissions scenario;
Percent change is relative to 1984-2013 average
PRELIMINARY DATA

Central Indiana Average

Change in Subsurface Tile Drainflow

	2050s	2080s
Winter Change	**+27%**	**+50%**

Future data based on high emissions scenario;
Percent change is relative to 1984-2013 average
PRELIMINARY DATA

Central Indiana Average

High Streamflows

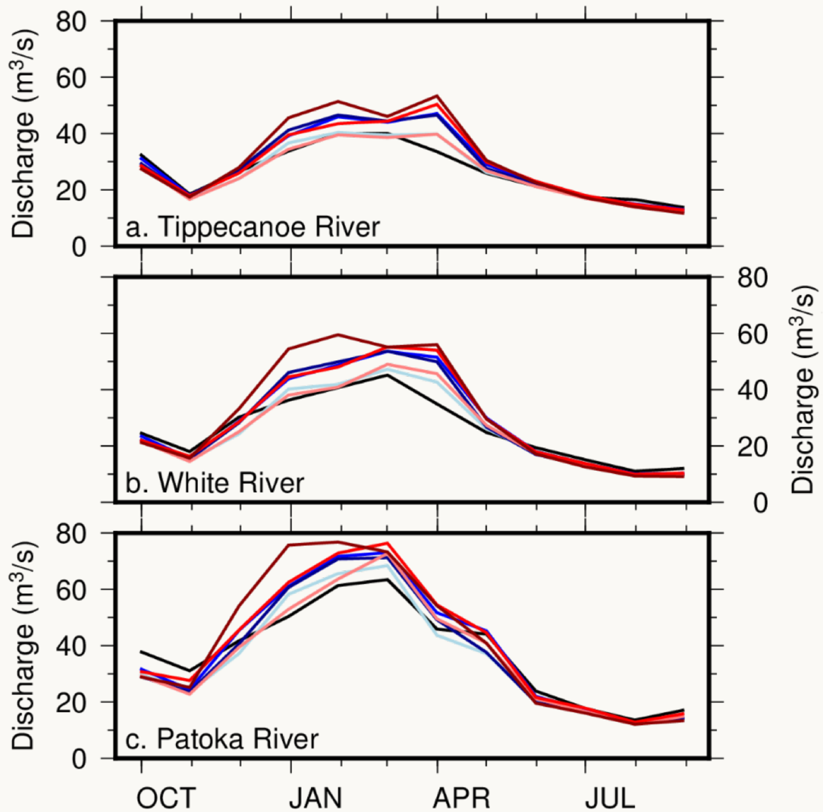
Events in the top 10% of high flows

	2050s	2080s
Annual Change	**+12%**	**+15%**

Future data based on high emissions scenario;
Percent change is relative to 1984-2013 average
PRELIMINARY DATA

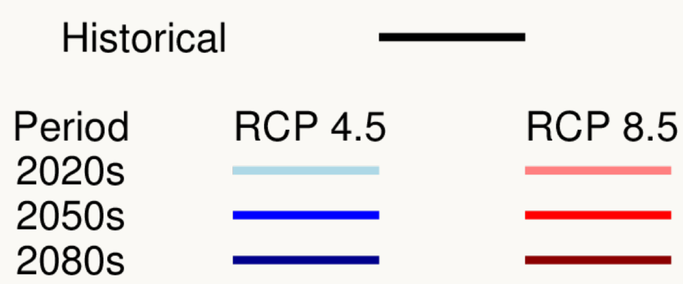
Central Indiana Average

Changes in Monthly Streamflow

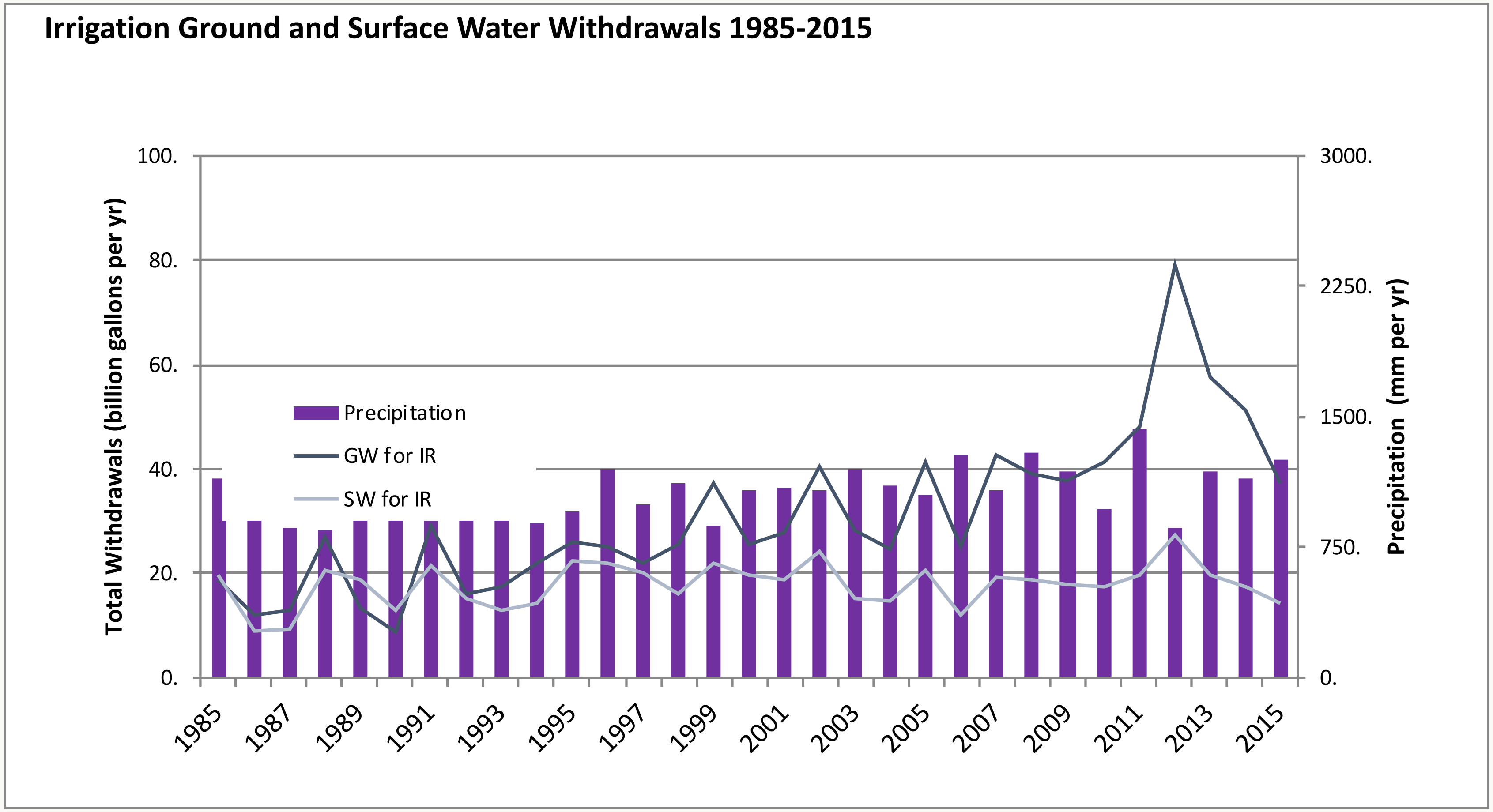


› Winter and spring flows increase

› Summer flows stay the same or decrease



Changing Water Demand



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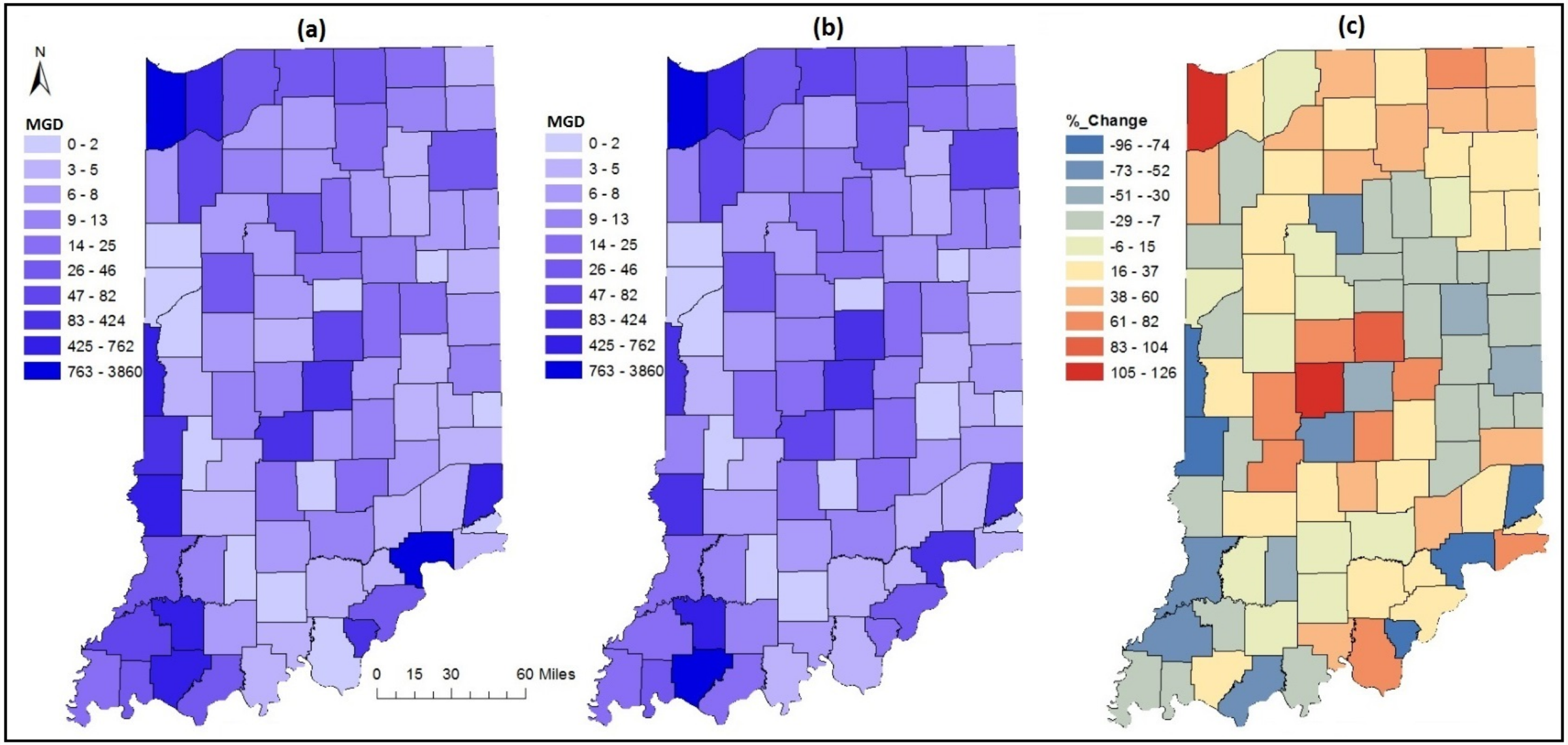
Changing Water Demand



Recent water conflicts in the news

"Water wells drying up in Jasper Co." WLFI, Wednesday, August 1, 2012

"Some Benton Co. residents without water blame farmer's new irrigation system",
RTV 6, The Indy Channel

"Entire state under water shortage warning", Journal Gazette

"Numerous factors could be causing water problems", Rensselaer Republican, Tuesday, July 31, 2012

"Groundwater 'dries up in Benton County: Irrigator may be liable if town's residents have to dig deeper for water, state official says'", Lafayette Journal and Courier, July 17, 2013

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Adaptation and Mitigation

› BMP effectiveness

› Natural habitat/wetland restoration

› Infrastructural changes

› Water regulation changes

› Economic impacts

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What can/should we do to manage future water resources?

Management

- In-year water management will become increasingly important as winter and spring excess will be followed by summer and fall deficits.
- This will require increased short-term water management to mitigate spring flooding and wet conditions, while increasing storage or groundwater recharge so that more of that excess water is available during the growing season.

Management

- Overall distribution of daily flows will increase by the end of the century for Indiana's rivers.
- Higher mean and low flows due to overall wetter annual trends mean that surface water will become more available, but increases in high flows and the increased risk of larger peak flows mean that water infrastructure should be evaluated for future flow conditions.
- Groundwater storage will also be affected by increased infiltration earlier in the year.

Management

- While annual conditions will be wetter in the future, the need for drought risk management will also increase.
- Specifically, we will need better information on groundwater storage and long-term changes in its availability, given that it appears to already be in decline in some parts of the state.

Management

- Existing Agricultural and Stormwater Management practices for water quality management are expected to be less effective in the future because of the change in seasonal water availability.
- Wetter spring conditions in particular are likely to overwhelm some practices and bypass others through increased subsurface drainage flows.
- Practices such as controlled drainage could play an important role in addressing these challenges.
- Practices relying on vegetation will have to deal with increased spring wetness and summer dryness.

Adaptation

- Climate is variable
- We already design and build for a variable climate
- We need to plan for increased variability

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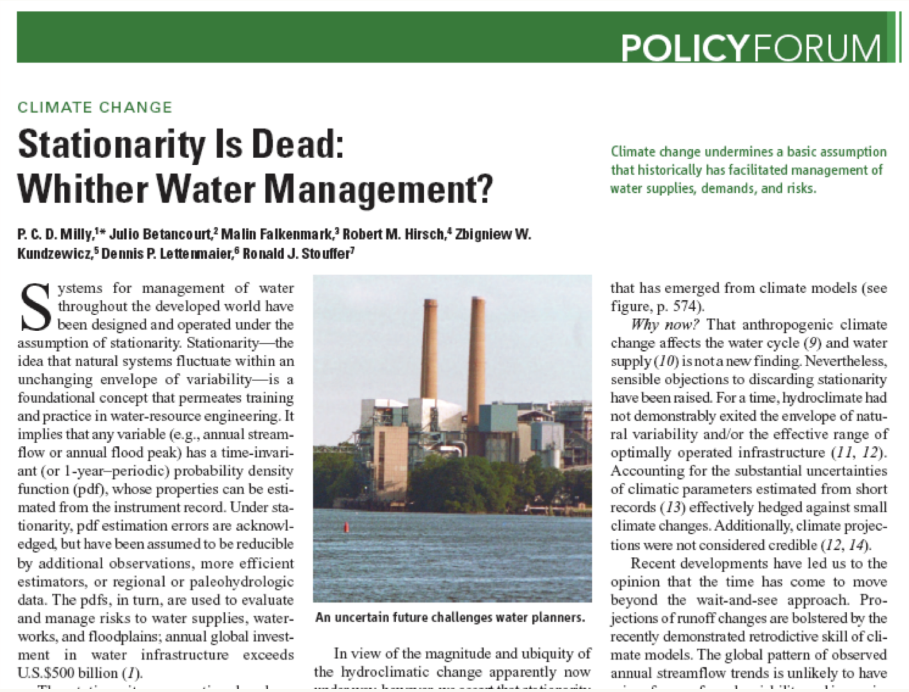
Adaptation

- Stationarity is the statistical assumption that variability in the future is constrained by what we have observed in the past.
  - Is stationarity dead?
  - Or did it never exist?
- How do we plan for the future when we cannot rely on the past to predict that future?



POLICYFORUM

CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,[1*] Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Systems for management of water throughout the developed world have been designed and operated under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a foundational concept that permeates training and practice in water-resource engineering. It implies that any variable (e.g., annual streamflow or annual flood peak) has a time-invariant (or 1-year–periodic) probability density function (pdf), whose properties can be estimated from the instrument record. Under stationarity, pdf estimation errors are acknowledged, but have been assumed to be reducible by additional observations, more efficient estimators, or regional or paleohydrologic data. The pdfs, in turn, are used to evaluate and manage risks to water supplies, waterworks, and floodplains; annual global investment in water infrastructure exceeds U.S.$500 billion (*1*).

An uncertain future challenges water planners.

In view of the magnitude and ubiquity of the hydroclimatic change apparently now

that has emerged from climate models (see figure, p. 574).

Why now? That anthropogenic climate change affects the water cycle (*9*) and water supply (*10*) is not a new finding. Nevertheless, sensible objections to discarding stationarity have been raised. For a time, hydroclimate had not demonstrably exited the envelope of natural variability and/or the effective range of optimally operated infrastructure (*11*, *12*). Accounting for the substantial uncertainties of climatic parameters estimated from short records (*13*) effectively hedged against small climate changes. Additionally, climate projections were not considered credible (*12*, *14*).

Recent developments have led us to the opinion that the time has come to move beyond the wait-and-see approach. Projections of runoff changes are bolstered by the recently demonstrated retrodictive skill of climate models. The global pattern of observed annual streamflow trends is unlikely to have

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Thank You!

For more information, go to
https://www.agry.purdue.edu/hydrology
https://www.purdue.edu/climate